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Analysis of Built Environment Features and Their Effects on Freight Activities

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Abstract

This study analyses truck parking citation data in Chicago to identify factors that affect concentration of high density of violations. Analysis of hot spots using a Geographic Information System (GIS) identified problem areas that are often along the major expressways as well as pockets of cold spots near the downtown. Regression analysis revealed two contrasting factors at play. One set of variables indicate that truck parking problems can be exacerbated by concentrations of food businesses in transit-oriented neighbourhoods. On the other hand, wealthy, stable neighbourhoods can present problems for truck parking.

Keywords: Truck parking, parking citations, built environment

1. Introduction

While nearly every driver can recall experiences with frustrations and confusion caused by illegally parked delivery or service vehicles, there have not been many studies that actually examined their impacts. One exception, a study by Han, Chin, Franzese & Hwang (2005) estimated that conservatively, illegal parking of parcel delivery vehicles is the third leading cause of urban non-recurring (i.e. not due to traffic volume) congestion behind crashes

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and construction. They estimated that in large urban areas in the U.S, a total delay caused by illegally parked pick-up/delivery vehicles to be 500 million vehicle hours annually costing some $10 billion in lost time. Surprisingly, however, there has been very little effort to reduce truck-related congestion in urban areas. Especially, when it comes to studies of built environment factors such as land use, streetscape, and urban design, to our knowledge, there has been only one paper by Pivo (2002) that examined street design features in Seattle. Pivo's research relied on the interviews and observations to develop some recommendations for improvements. His effort, however, focused on improving truck operations and did not investigate the cause of truck-related congestion. Some studies, e.g. a study of strategies aimed at improving truck operations in Washington, D.C. (U.S. Department of Transportation, 2009), developed recommendations for improving truck operations and mitigating truck-related congestion, but they are based on interviews and observations without careful analysis of the actual impacts of the recommended measures.

A recent study in New York City (Jaller, Holguin-Veras & Hodge, 2013) developed models for truck parking demand (Holguin-Veras, Jaller, Destro, Ban, Lawson & Levinson, 2011; Lawson, Holguin-Veras, Sánchez-Díaz, Jaller, Campbell & Powers, 2012) and curb space availability using tax map and property information data. While that study is, to our knowledge, the only example of an academic effort to systematically examine demand-supply balance for trucks for a large urban area, the authors had to employ several key assumptions regarding deliveries per stop and service hours. Another recent study by Conway, Thuillier, Dornhelm & Lownes (2013) examined, using video recordings, the frequency of conflicts between bicycles and trucks in New York City. They found that surprisingly, the frequency of conflicts tends to be higher for areas with lower business densities. They attributed this phenomenon to the fact that the blocks that are occupied by a small number of large business establishments tend to experience more intense, and possibly more concentrated, truck activities.

While it is encouraging to see an increased interest in the topic of truck-related congestion and conflicts in urban areas, many knowledge gaps still remain. The aim of this paper is to present analyses of truck parking problems in urban areas using truck parking violation records in Chicago. The study strives to identify land use and socioeconomic factors that are associated with the frequency of truck parking violations in Chicago. Parking violation data are an effective indicator of truck parking problems and hot spots because they directly capture the presence of parking problems. One of the issues that arise with the use of parking ticket data is the potential variability in the level of enforcement effort. In this study, we use the proportion of total parking violations that are attributed to trucks to account for the enforcement intensity.

2. Analysis

2.1. Data

The data for parking violations were obtained from the City of Chicago. The City of Chicago is approximately 600 km^2 in land area and home to 2.7 million people, inhabiting a total of 1.2 million housing units. Chicago is the third largest city in the U.S by population. The dataset obtained for this study includes all the parking citations issued in the city during a 12-month period between September 1, 2011 and August 31, 2012. The descriptive analyses provided in the following section is based on the 12-month data, however, for the hot spot and regression analyses, we extracted the tickets that were issued during August 2012 to limit the number of data points that needed to be geocoded in the GIS. The August 2012 dataset contains a total of 216,714 citations, of which 11,398 were attributed to trucks.

2.2. Descriptive analysis

Table 1 shows the breakdown of types of violations cited in the tickets issued during the 12-month period. It should be noted that the data set only includes citations issued during the parking enforcement activities, and other types of violations given, e.g. Vehicle Type Prohibited, Plate Violation, Equipment, Operation, and Seatbelt, shown in the table were incidentally included in the dataset. In some cases, those other violations are issued in addition to a parking citation. For example, if a truck is parked illegally on a street that has a truck restriction, then the enforcement officer may issue a parking ticket and a citation for the vehicle type prohibited.

As shown, a large share, many of the total cases are attributed to violations that are not parking related. Our analysis includes these incidental citations since the prevalence of those violations indicates high-stress environment for trucks (and other travelers who share those spaces).

In Chicago, it is rare to find on-street parking spaces that are not regulated by parking meters or residential permit systems. As such, expired meter and parking permit violations account for 23.5% of total citations. When snow accumulation exceeds 2 inches (5.1 cm), certain designated “snow routes” become no-parking streets in order to provide room for the snow removing vehicles to operate. Violation of this snow route parking rule, combined with street cleaning and special events account for 6.7% of citations. Interestingly, only a small number of tickets are given for double-parking, which Han, Chin, Franzese & Hwang (2005) identified as the fourth leading cause of urban non-recurring congestion. In one year, truck parking tickets accounted for a total of $8.2 million in fines. The average amount of fines was $62 per violation.

Table 1. Types of Truck Parking Citations

Type of violation	Sum of Fine	Citations	% of All Citations
Vehicle Type Prohibited	$ 1,041,425	37,145	29.5%
No Parking Zone	$ 1,520,050	22,193	17.6%
Expired Meter	$ 837,350	16,221	12.9%
Plate violation*	$ 902,055	15,043	11.9%
Parking Permit	$ 1,939,665	13,297	10.6%
Street Cleaning, Snow, Special Event	$ 423,920	8,414	6.7%
Block Access	$ 663,260	5,254	4.2%
Bus Lane or Stop	$ 271,900	2,746	2.2%
Fire Hydrant/Lane	$ 196,000	1,938	1.5%
Double Parking	$ 163,200	1,632	1.3%
Equipment*	$ 130,800	919	0.7%
Curb Loading Zone	$ 27,000	450	0.4%
Disabled Parking	$ 71,800	359	0.3%
Operation*	$ 27,850	217	0.2%
Seatbelt*	$ 4,175	167	0.1%
Improper Parking	$ 1,300	26	0.0%
Unattended Veh.	$ 1,125	15	0.0%
Grand Total	$ 8,222,875	126,036	

* - Indicates violations that are not parking related.

Fig. 1 depicts the time-of-day distribution of parking tickets. This figure shows that the peak period for trucks to receive parking citations begins around 7am, reaches the peak around 9:30am, and continues till 10:30am. Although there is no reliable 24-hour truck counts in the city, this pattern largely coincides with the peaking of truck activities that truck operators identified through past interviews by the authors of this paper. The slight dip in the frequency around 9am reflects the practice of truck drivers avoiding the peak of the morning rush hour in the city. Many of the truck deliveries are made before (between 7am and 8:30am) or after (between 9:30am and 10:30am) the peak of morning rush.

Fig. 2 shows the spatial distribution of 11,398 parking citations issued to trucks in August 2012. This figure shows the downtown of the city as the area that sees the most intense concentration of violations. Also, there are three distinct corridors, all radiating outward from the downtown, that form the bands of high-violation areas. They are: 1) the corridor stretching along Lake Michigan to the north, 2) the area along Interstate 90/94 that leads toward O’Hare Airport, and 3) areas along I-55 heading southwest. The first area is a mix of dense residential areas with commercial businesses. The second area is comprised of residential, commercial, and some industrial neighbourhoods. The third area includes mostly industrial developments that go back to the early days of Chicago. The figure shows that truck parking citations are mostly concentrated in the north half of the city where employment is more abundant compared with the southern half.

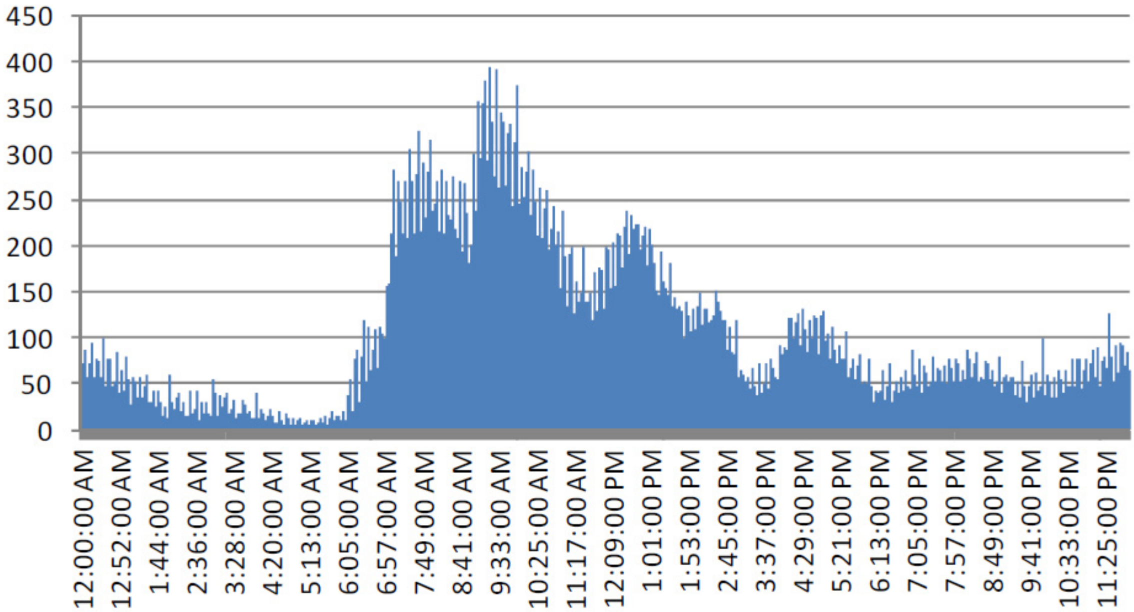

Fig. 1. Time of day distribution of truck parking citation

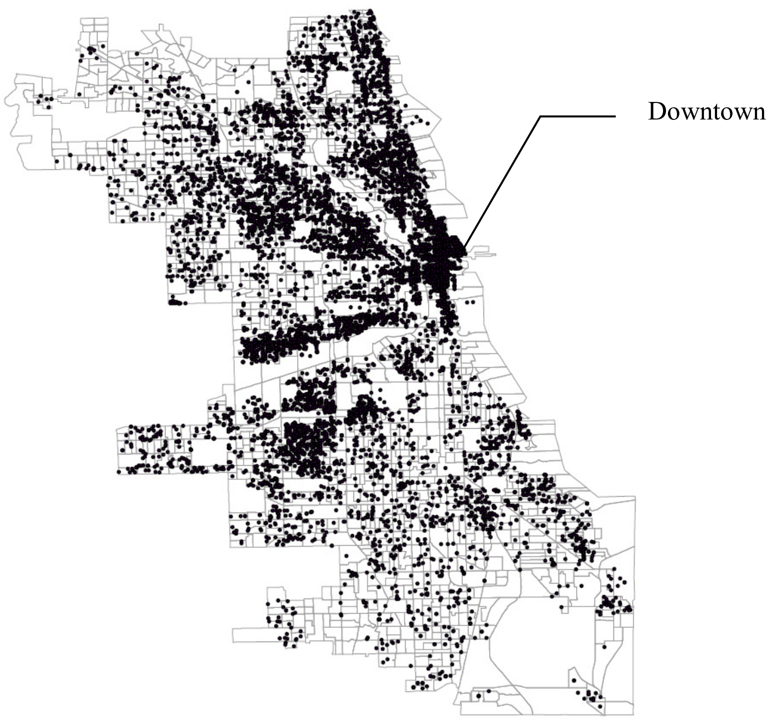

Fig 2. Truck tickets given in Chicago during August 2012

2.3 Hot spot analysis

The variable of interest for this part of the study is the density of truck parking violations, calculated at the Census block group level. Each block group contains between 600 and 3000 residents, with the optimum value of 1500 people (US Census Bureau, 2013). As such, the size of block groups varies significantly across an urban area. The average size of block groups in the data set is 0.025 km^2. Densities are calculated based on the area, rather than road length, within each block group. If the road density varies among the block groups, the area-based density may not be the right indicator to measure the concentration of parking violations since areas with denser networks are likely to see more parking violations. However, the street density in Chicago is relatively uniform except for the core areas knows as the "Loop" since Chicago's road network conforms to a grid system that forms standard Chicago blocks (200 meters by 200 meters).

Getis-Ord *G* statistics are commonly used to identify "hot spots" where unusually high or low levels of observations (parking violations in this case) are clustered in some areas (Ord & Getis, 1995).

The *G* statistic is calculated by

$$G_i(d) = \frac{\sum_j w_{ij} x_j}{\sum_j x_j} \tag{1}$$

where, $G_i(d)$ is the G statistic calculated for location i (the centre of the cluster), x_j is the variable of interest, observed at location *j*, w_{ij} is the spatial weight metrics that is 1 if *j* is within a predefined distance, *d*, from the focal point of the cluster, *i*, and zero otherwise. The numerator is the sum of *x* values that are within the predefined distance, *d*, from the focal point, and the denominator is the sum of all the *x* values in the data set. Thus, $G_i(d)$, is simply the proportion of *x* values that are neighbours of location *i* with respect to the sum of all *x* values. Getis and Ord showed that under most conditions, $G_i(d)$, is asymptotically normal, and thus inferential statistics can be performed using z-test (with the null hypothesis being spatial independence of the *x* variable).

Fig. 3 shows the hot and cold spots identified using the standardized (in Z-value) Getis-Ord *G* statistic. This figure clearly shows that the density of parking violations is the greatest in the CBD and the surrounding areas, and decreases gradually toward the periphery. However, there is a pocket of an area near the CBD, the sliver just south of the downtown, that is shown to be neither a hot nor cold spot. While this area is home to numerous distribution centres and rail yards (this area was home to the Union Stock Yards, the famed meat packing facilities, till the 1970s), roads are designed to accommodate large trucks and the land use resembles suburban industrial parks. While more study will be needed to determine the relationship between the parking violation density and road design and land use, it is clear that the stress level for trucks, as far as parking is concerned, seems to be much lower there than other areas near the downtown.

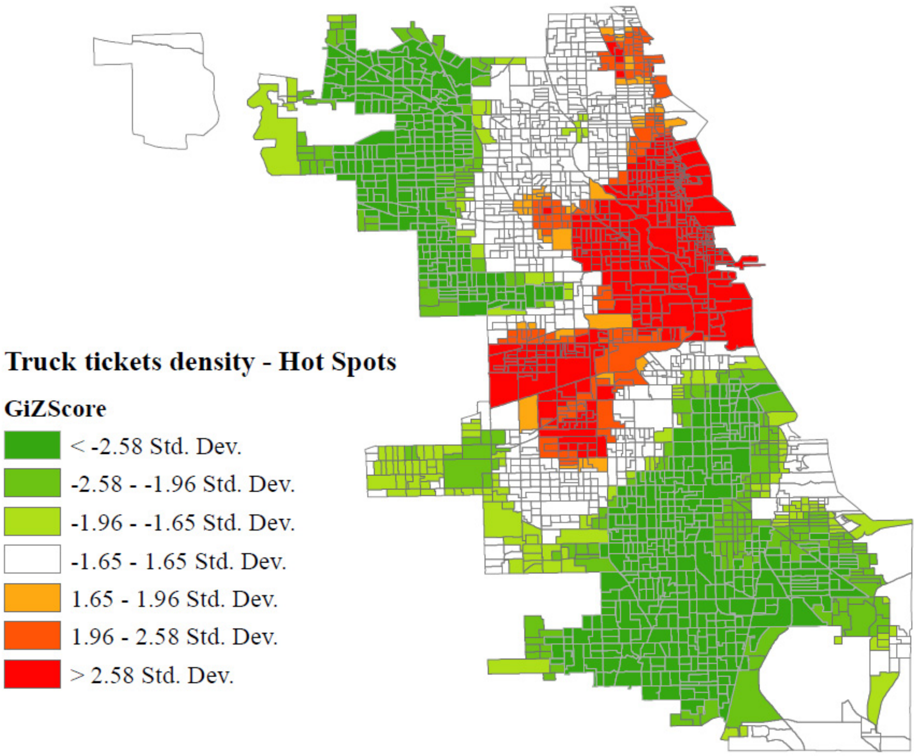

Fig. 3 Truck ticket density hot spots

2.4 Regression

The next analysis examines the relationship between the truck ticket density and various socioeconomic and built environment factors to explain the variation in the former. The socioeconomic variables are obtained from a combination of sources that include the US Census of Population, US Economic Census, proprietary consumer survey databases, and Dun and Bradstreet business database. All the variables are aggregated at the Census block group level.

Independent variables include the number of establishments and employment at the NAICS 2-digit level, household income, poverty level, population density, total retail sales, total merchandize sale, sales from food services, average annual residential turnover rate, vehicle availability (average vehicle per household and vehicle density), work trip mode shares, housing stock occupancy rate, age of residential structures, share of housing units across various building sizes (single detached, duplex, 3-9 units buildings, etc.), participation rate in on-line shopping, average rents and average house values, crime rate, age, language spoken at home, and average parcel size.

The regression model was constructed using a combination of try-and-error and the backward elimination process. The final model, shown in Table 3, achieved a satisfactory level of fit, with an adjusted R-square of 0.637, and Durbin-Watson test does not show evidence of severe deviation from normality after the log transformation of the dependent variable.

Table 3. Regression results

Dependent variable: LOG_TRK_DENS (Log of truck ticket density)
N=1764, Adj. $R^2 = 0.637$, Durbin_Watson D = 1.63

Independent variable	Description	Coefficient estimates	t-stat	p-Value
CONSTANT		-5.67	-40.5	0.00
LG_PAX_DEN	Log of passenger vehicle parking ticket density	0.678	34.7	0.00
LG_AVG_PARC	Log of average parcel size	-0.132	-5.28	0.00
SPEAKSPA_P	% of household speaking Spanish	0.00833	13.8	0.00
TENURE_GT5	% of residents with tenure over 5 yrs	0.00421	2.02	0.04
NO_VEH_PER	% of 0 vehicle household	0.00501	3.69	0.00
MEDHHINC	Median household income	0.00263	3.85	0.00
FOOD_SALE	Total sale of food services	0.000019	6.39	0.00

The model includes the log of the density of tickets issued to passenger vehicles, LOG_PAX_DEN, to control for the intensity of enforcement with an assumption that it reflects the number of parking enforcement and police officers in the area. In the areas that are patrolled heavily, truck parking violations have a higher probability of being ticketed compared with areas with a low level of enforcement. The GIS layer of parcel map for the city of Chicago, compiled by the tax assessor office of Cook County, was used to calculate the average parcel size. Since the average parcel size reflects building density within a block group, it can be said that in areas with a lower building density, for example single-detached family neighbourhoods or industrial developments, truck parking citations are less frequent. The positive coefficient for the residential tenure and median household income indicates that trucks tend to receive more parking tickets in stable, wealthy neighbourhoods. The positive coefficient for the total food service sales suggests that in areas with a greater concentration of restaurants, trucks tend to receive more citations. Also, in neighbourhoods with higher Latino population, trucks tend to receive more citations.

Overall, the results suggest that there are two opposing factors at play. Variables such as household income, parcel size and residential tenure suggest that parking problems for trucks are more prevalent in neighbourhoods that are quiet and less dense. However, this may be attributed to the fact that many of the citations in the data set are actually for violating truck route regulations, i.e. “vehicle type prohibited”. Another factor may be that in residential neighbourhoods, most on-street parking spots are regulated by residential permits and competition for space is intense in most of these neighbourhoods. The areas along Interstate 55 that were identified as having a high concentration of citations fit this description. On the other hand, the presence of variables such as food sales and percent of households with no vehicles suggests that, as was seen in the hot spot analysis, the areas near the downtown and to the north, e.g. neighbourhoods such as Gold Coast and Wrigleyville, where development is predominantly mixed commercial/residential with good transit services, are associated with greater density of parking citations given to trucks. Another point of note is that neither employment levels, total nor industry specific, were strongly associated with citation density. None of the industry employment levels was statistically significant. Even trucking and warehousing, manufacturing, and construction employment did not enter the model as they were all statistically insignificant.

3. Conclusion

This study examined the relationship between spatial distribution/concentration of parking violations involving trucks and various socioeconomic and built environment factors. Hot spot analysis was conducted using the Getis-Ord statistic. The analysis showed that parking problems are generally worse within or near the downtown and become less serious away from the core areas. However, it was also found that truck parking does not seem to be a serious issue in the part of the city that has been home to industrial sites for a long time. Most likely, this is due to the combination of street design and low building density that are contributing to the reduced level of parking problems in these areas.

Regression analysis seemed to capture two opposite effects. There is evidence that suggest truck parking problems are more severe in the stable and wealthy neighbourhoods. Meanwhile, serious parking problems also seem to exist in mixed-use, transit-oriented neighbourhoods. These results mostly match the characteristics of the neighbourhoods that were identified in the hot spot analysis.

While this study sheds lights on built environment factors that seem to affect truck-related problems in urban settings, it will require more fine-grained analysis, perhaps examining specific types of violations and interviewing truck operators, to fully understand the cause-and-effect relationships.

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